

MARCH 15, 1920

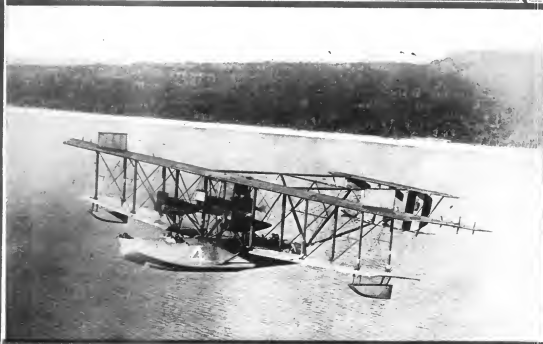
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# AVIATION

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# AERONAUTICAL ENGINEERING

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VOLUME VIII

Number 4

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No. 4

**I**NCREASING popular interest in aircraft is reflected in the decision of the airplane manufacturers to make the New York, Chicago and San Francisco shows permanent national events.

The next featured step would be representative outdoor exhibitions on various parts of the country during the season of best flying weather. Passenger carrying, flying exhibitions and especially competitive hand-to-hand flying would appeal to the sport interest of thousands. They would provide an actual means of converting interest aroused by the big indoor winter shows into actual sales of aircraft through practical demonstration and operation.

Creating a well thought out itinerary, there is no reason why the exhibition places should not be organized into a "commercial quadrate" and fly as a unit to the different exhibition points. The publicity and human interest features of such a quadrate readily suggest themselves. At the same time great saving and shipping expenses would be eliminated.

Chambers of Commerce and municipalities would undoubtedly cooperate for even reasons, and the substantial support of flying clubs and distributors of planes could well be counted upon.

Such a movement should be started by the manufacturers of commercial planes at once, if not for 1929 then for 1931.

### American Airship Pioneer

One hundred years ago, Rufus Porter, an inventor from New York, published in a local scientific journal a summary on the propulsion of balloons which holds an important place in the annals of airship development, although it did not at the time attract the attention it deserved and soon fell into oblivion.

Porter's proposed airship was chiefly remarkable for that it had a streamline envelope—an important feature, the invention of which is generally credited to Swiss airship pioneers, the outcome of which Porter's design antedated by some forty years. In order of chronology, the sequence Porter's proposed airship comes right after the egg-shaped balloon of General Bessmer, the founder of the science of airship design.

Now that the United States Navy has decided to build up a fleet of large rigid airships, it would seem the fitting thing to give them important credit the names of American airship pioneers. The memory of Rufus Porter undoubtedly deserves to be thus honored among the first. Sell other names suggest themselves for such recognition.

Among such one might mention Dr. Jeffers, who accompanied the Frenchman Blanchard on the first balloon trip across the English channel, in 1784; John Woe, the famous balloonist of the late forties and fifties, who invented the rip panel; and Benjamin Franklin, whose correspondence contains numerous references to the earliest balloon experiments in France.

### Sweaged Wire

Sweaged wire is nothing but hard wire, threaded at the ends, but together with suitably unthreaded threaded cleaves, sweaged wire permits a considerable simplification in the assembly of a plane. It permits the construction of turnbuckles, and avoids the always difficult operation of attaching hard wire to a lag.

Experimentation on sweaged wire has now reached the stage where it can be manufactured with complete assurance of the required strength. Where the difficulty arises, it is in the fact that every airplane builder's requirements are different, as regards size and length of wire. No manufacturer can be expected to keep in stock an indefinite number of sizes and lengths to meet every possible requirement. At the same time, when a machine is going into production, there should be an very great difficulty for the builder to make his own sweaged wire and there are at least two manufacturers in the country who are willing to consider the manufacture of sweaged wire, to meet any given requirements in suitable quantities.

### Oil Reclamation

There is no doubt that with the present dry fuel and oil, all lubricants are largely diluted in use, and the losses caused by dilution are serious, as they mean loss of power and increase in wear.

While a great deal may be expected both at the hands of the engine designer and the oil refiner to improve the situation, it is interesting for airplane men to consider that during the war, the Air Service designed and installed, at thirty flying fields, a simple system of reclamation, by which 70 per cent of the used oil was reclaimed, and made available for reuse.

The reclaimed oil was actually a better lubricant than the original oil.

Oil reclaimers can be installed in every commercial engine, and it is only necessary to have clean for their operation.

Reclamation costs do not exceed ten cents a gallon. Since the airplanes are now a commercial proposition, the possibilities of reclamation, cannot be neglected.

# General Electric Turbo Supercharger for Airplanes

By Sanford A. Moss

An airplane flying at high altitude receives air at a comparatively low density. At 10,000 ft. altitude the density is practically half that at sea level. This means that a given volume contains half as much actual air by weight. The cylinders of an airplane engine are therefore charged with an explosive mixture which has about half the value of a charge at sea level. The engine actually delivers about half its sea level power at 10,000 ft.

Both the decrease of temperature at high altitude and the decrease of pressure have effect in fixing the high altitude density. Both the decrease of temperature and the decrease of weight of the charge affect the combustion at high altitude. The fitted clearance volume and the decreased initial pressure

shape of the impeller blades and the passages leading air to and from the impeller are so arranged as to give efficiency very much greater than that of the same type of fan blower, so that the apparatus forms a satisfactory means for compressing air to superdense pressures. The General Electric Co. has developed a line of single stage centrifugal compressors for compressing air from 5 to 5 ft. per sq. in. above atmosphere, for use for many industrial purposes, as well as a line of multistage machines for compressing air and gas up to pressures of 20 ft. in. above atmosphere. This business has grown rapidly and this past year the total sales will approximate a million and a half dollars.

The turbo supercharger is a combination of a gas turbine and a centrifugal compressor, mounted as a part of a surplus gas turbine engine. The hot products of combustion from the engine exhaust, are recovered onto the turbine and furnish power whereby a centrifugal compressor mounted on the same shaft, which compresses air for supply to the supercharger. A more detailed description is given later.

In the latter part of 1917 the National Advisory Committee for Aeronautics requested the assistance of the General Electric Co. in the development of the turbo-supercharger as the United States. Our experience with gas turbines and centrifugal compressors led us to be greatly interested and the work was pushed rapidly during the war. An apparatus was constructed and gotten into operation on an airplane engine some six feet.

After a period of development had been gone through with the stage was reached where nothing more could be done except at high altitude. However, since the development was so completely advanced, it seemed as though flight, the entire testing apparatus was taken to the summit of Pike's Peak. Here a further period of development was gone through with the apparatus was finally gotten into satisfactory working order so that the engine engine developed the same power at the summit of Pike's Peak as it originally had near sea level. Arrangements had been started for installing the apparatus on an airplane when the situation deteriorated. The engine was not used in the manner intended, but by delay officials after the armistice, led to a suspension of the work and the apparatus was finally installed on an airplane. A very good description of the first

The increase of power at high altitude was such as to give an entirely new set of conditions from those under which the engine originally operated. This required various changes in the entire airplane apparatus and development was made of proper radiators, propellers, pressure systems, cooling systems and so on. The work has been proceeding satisfactorily for some time.

Development work on the turbo supercharger is also being carried on in France independently of our own work. So far the results are similar. The first part of the French work, our own apparatus is of our larger size. We are supercharging

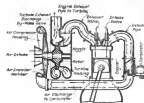


FIG. 1. DESIGN OF TURBO SUPERCHARGER

give a decrease of compression pressure resulting in a loss of efficiency. There is a tendency of engine which gives us a great much the decrease in engine power very easily proportional to the decrease in density.

At high altitude the resistance of the air to the motion of the impellers is decreased in proportion to the decrease of density. The power required to drive a given airplane speed is, therefore, greatly reduced. However, the engine power has been so reduced that the actual net result is a considerable decrease in airplane speed. When the engine power is maintained at the sea level value, there is, however, a considerable increase of speed at high altitude.

Fixing the system of an internal combustion engine with a charge greater than that which would normally occur, is called "supercharging." Methods of doing this are supercharger and exhaust valve engaged the situation of a great many experiments.

The gas turbine is a prime mover in which highly heated products of combustion impinge directly on a turbine wheel. The high lateral velocity of the gas imparts and the rapid displacement of the responding reaction by the steam turbine, due to its many stages upon low, of course, caused a great deal of effort to be spent upon some combination of either of the two, in the form of a gas turbine. Many inventors have proposed various types of gas turbines and a number of them have been gotten into successful machine operation. However, no type has yet shown sufficiently good efficiency to warrant commercial use. The engineers of the General Electric Co. have very closely followed the various gas turbine developments and have been intimately in touch with the situation for many years.

In 1913 the General Electric Co. first began work on the Centrifugal Compressor. This is an apparatus similar to the fan blower except that the



FIG. 2. GENERAL ELECTRIC TURBO SUPERCHARGER FOR PIERCE'S PEAK TEST

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a light airplane motor and are carrying the supercharging to higher altitudes. The mechanical details of the French and General Electric apparatus were developed independently and are quite different. A turbo supercharger, similar to the French one was started in this country, but was modified considerably before final completion. Work on this apparatus has not been carried to a sufficient extent.

Our work was originally started at the suggestion of Dr. W. P. Dorned, then chairman of the National Advisory Committee for Aeronautics, who knew of our long experience with gas turbines and centrifugal compressors. It has since been

extremely elastic. The work then for accomplished has demonstrated the validity of the fundamental premises and has disclosed the problems of detail which must be met.

## Mechanical Problems of Supercharging

The General Electric supercharger has for construction been designed to give sea level absolute pressure at an altitude of 10,000 ft., which involves a compressor which develops the absolute pressure of the air. The pressure ratio, with the quantity of air handled, given about 100 ft. per sq. in. required for the compressor. The design of a complete power plant of this size is not a meeting airplane engine, with one wheel and located as well and superior the flying characteristics of the plane has, if so, a second wheel problem. The possibility of doing the carrying of the supercharger by engine power instead of by the exhaust gases, of course required itself.

Indeed, observation of an engine exhausting to the usual way into the atmosphere, discharges steam through the short, not short, with the same sea level absolute exhaust value in view, makes it seem almost impossible to pass them out through pipes with a pressure difference above the surrounding atmosphere equal to its exhaust pressure, and more closed still to propose to obtain power by discharging them out into space into a further wheel, making at 20,000 ft. a second wheel problem. Nevertheless, the turbo supercharger has made steady advance with entirely successful operation, with the power drive supercharger has never failed in spite of such effort.

Such experience with the operation of the gas turbine led the writer to prefer its problem in those of the dry, the mechanical of a supercharger operated from the engine. The turbine involves mainly the addition to the compressor of a single extra wheel, designed for the maximum, with no extra bearing. The engine drives exhaust valves or 50 ft. transmitters with multiplicity of pipes, bearings, valves, belts and the like. These other means are too long and the engine the supercharger is not in use at low altitudes, and very serious problems of construction when the supercharger is to be taken into service, since the engine will then running at its full speed of about 1000 rpm.

It must be recalled, there is turbine which has been designed to reduce, that it is much the engine propeller.

The critical mechanical and aerodynamic has been given to be a very efficient exhaust valve and a small, light, and efficient and radiator is needed in any event and the design of wheels for withdrawing the increased pressure difference of the turbo supercharger has been considerable.

## Power for Turbo and Engine Drive Superchargers

An efficient turbo supercharger theoretically develops from the indicated horsepower of the airplane engine, an amount corresponding to the difference between sea level absolute pressure and altitude pressure. There is also the extra work done during the exhaust stroke. The theoretical power available



FIG. 3. TEST OF TURBO SUPERCHARGER

started on under the supercharger on various times of Col. J. G. Vincent, Col. T. H. Bass, Maj. H. C. Hanson, Maj. G. B. A. Hallist and Maj. E. W. Sommer. Maj. Hallist has led charge of the development since 1917, and has given considerable study to the matter of superchargers in general. Reference may be made to his paper, read before the Society of Automobile Engineers, Jan. 6, 1918, and published in the S. A. E. Journal for November, 1918. This contains an account of various power drive and sea level superchargers which have been experimented upon.

## The Turbo Supercharger Cycle

Fig. 3 gives a detailed description of the principles of the turbo supercharger. The exhaust of the airplane engine is received by an exhaust manifold which leads it to a nozzle chamber carrying exhaust wheels which discharge it into the buckets of a turbine wheel. On the same shaft as this turbine wheel is mounted a centrifugal compressor. The compression of the air from the surrounding altitude low pressure to approximately sea level pressure, and delivers it to or as discharge chamber which regulates the carburetor.

The turbine engine as of such use as to maintain within the exhaust manifold and nozzle box a pressure approximately equal to that at sea level. The engine between the pressure and the altitude low pressure gives a constant drop for the exhaust gases which furnishes the power to turn the system.

Due to the temperature, this power input suffices to give the desired compression and also to supply the inevitable losses. However, in order to avoid such power on the engine, the exhaust air is cooled, both turbine and compressor wheel being designed with constant efficiency to efficiency.

With an efficient supercharger, when the engine is at high altitude it exhausts at normal sea level pressure and retains as air at the supercharger at normal sea level pressure. Hence normal sea level pressure is delivered at altitude up to the maximum for which the supercharger is designed, so that the plane speed will increase uniformly as the altitude greatly decreases.

In order to reach the ideal state, there are various secondary problems such as temperature rise of compression, slight deflection of oxygen at high altitudes, effect of the propeller on engine speed, and various other



FIG. 4. TEST OF TURBO SUPERCHARGER

able for driving the turbo supercharger is greater than this, however, owing to the fact that there is available not only the energy due to the thrust, pressure difference above mentioned, but also the energy of perfect expansion from the higher to the lower pressure. If there were no turbo supercharger the engine would waste this energy in useless pressure drop as the exhaust vapor expands. The turbine can utilize this energy. The use of these two amounts of available energy, multiplied by the efficiency of the turbine wheel, gives the shaft power delivered to the compressor.

For an engine driven supercharger compressor there is



FIG. 5. MONITORING AT PIER'S PEAK.

greater engine indicated power due to a lower exhaust pressure. However, the shaft power for the supercharger compressor must be transmitted through the engine connecting rod and crank shaft, with losses, and then through the supercharger driving mechanism with additional losses. The total shaft power thus transmitted from the engine, multiplied by the efficiency of these two transmissions, gives the shaft power delivered to the compressor. This is the same as for the turbo supercharger. For a Liberty motor of about 400 hp. and sea level power at 16,000 ft. altitude this power is 50 hp.

The compressor then is as follows: The turbo supercharger extracts from the engine indicated power, while power of expansion which would not otherwise be used, and has turbine wheel losses. The engine driven supercharger puts the indicated power through the engine (with some additional losses on the pass and bearings) and has engine and transmission

losses. Much actual efficiency there is probably not a great deal of difference between the gross extraction from engine power in the two cases. There is then the disadvantage of transmitting the supercharger power through the engine (pass and bearings), as well as through some mechanism between engine and supercharger, to be compared with the efficiency of the last power under pressure with no frictional advantages and delivery to the turbine wheel. An advantage mentioned, pointed out to date is in favor of the turbo supercharger and the writer feels that this is really due to its greater simplicity.

Engine driven superchargers with "positive pressure" blowers have been proposed. These have the additional disadvantage that while the blowers pressure loss of about two, there is an appreciable compression loss due to the fact that the machine only displaces air and has no direct means for compression.

It is to be noted that, although the power required to drive the supercharger is subtracted from the engine power, the remainder at high altitude with an efficient supercharger is equal to sea level power. That is, say, the supercharged engine delivers power enough to drive the supercharger as well as to deliver sea level power to the propeller. There is a net sum so far as strength for power. If the supercharger, with the supercharger power due to exhaust at the low altitude pressure of high altitude and without expenditure of power for

supercharging. Without a supercharger the engine has the advantage of a very low exhaust pressure, but the engine charge is so small that the gross power has the well known low value at altitude.

#### Supercharging Engines

Supercharging engines of various kinds, in which the engine crank case or the engine cylinders themselves are arranged for additional compression, have been discussed by May Hallett, and shown to give economy weight and simplicity as compared with a turbo supercharger.

A very simple form of supercharging has frequently been used where an engine of large displacement, but with very high compression ratios, has been fitted in a comparatively small plane. In such a case, the turbine could not be turned while the engine was at sea level since the compression would be excessive and engine operation would result, by way of rubbing of the driving effort on the engine of delivery of the full power corresponding to the displacement, with sea level charge. At altitude, however, a full charge at the altitude density is taken, and an increase of the high compression piston, thus is compressed to a proper amount for good operation. Some high altitude flights have been made in this way with a single test plane and engine with a displacement corresponding to 400 hp. at sea level. The power at high altitude was possibly 380 hp. A 180 hp. engine with a turbo supercharger would give the same altitude power and weight very much less.

Since such an engine has normal compression pressure at high altitude, the power will be very easily proportional to the density of the charge. There will be no loss of efficiency due to decrease of compression pressure. The altitude power will then vary directly with the critical displacement and inversely with the density of altitude.

May Hallett points out that with such an engine the weight is directly proportional to the displacement. Hence such an engine will weigh nearly twice as much as a supercharged engine with 16,000 ft. altitude condition, and nearly four times as much with 32,000 ft. condition where the density is one-fourth that at sea level. There is some indication from these figures due to the fact that the weight will not go up quite as fast as the displacement and because the supercharger weight is not negligible. However the situation is no more as is represented.

Engines have also been proposed with crank case compression, either with indirect connections or with a piston which is double-acting, with crank case side supercharger or single cylinder. However, with the minimum crank case clearance there suggested, the maximum compression pressure would not be sufficient to give supercharging at an appreciable altitude.

#### Design of the General Electric Superchargers

The machines used thus far have been designed to give sea



FIG. 6. REAR OF PIER'S PEAK TRINITY OTTAWA.

level pressure at 16,000 ft. altitude, which corresponds to a pressure ratio of about 2. The rated speed for these machines is 28,000 r.p.m. Sea level pressure has readily been obtained up to 22,000 ft. altitude, however. The control is entirely by hand operation of main gases, when permit of the design of some of the exhaust pipes.

The entire apparatus, exclusive of exhaust manifold and air discharge conduit, weighs about 300 lb. The exhaust manifold, containing the turbine, weighs nearly the same weight as separator parts with an supercharger.

The turbine and compressor wheel have diameters somewhat less than a foot. The turbine design has been hampered by necessity for application to existing engines and planes. It is, in principle, however, very simple. The turbine and compressor are integral with all parts arranged for the full possibilities of the construction.

The essential parts of the design are exhaust arrangements of ducts for cooling the various parts, means for accommodating the temperature expansion, means for handling the temperature which exist, and design of lock turbine and compressor to give absolute efficiency.

#### History of General Electric Supercharger

The construction of airplane, propeller, engine, radiator, cooling system, and supercharger are so intimately associated that it is difficult to tell where the complete system is operated at full speed at altitude. Altitude chambers exist for tests of engine alone, but none are arranged for inclusion of the propeller. What tests were possible were first run with the engine at constant altitude at the Lyons Works of the General Electric Company. Additional tests were run with the superchargers and Liberty motor on dynamometer stands at the Pratt & Whitney Division, and the Experimental Station of the Engineering Division of the Air Service.

These tests were necessarily made with nearly sea level air. The present turbo supercharging under such conditions involved increase of compression pressure, and the naturally dense propeller. Both sets of tests gave better for performance of the mechanical operation of the superchargers, but gave no information as to increase of engine power under altitude conditions. It could be seen everything was operating per schedule, but there was not sufficient vacuum to warrant an altitude flight.

During the initial development of the Liberty motor a testing expedition had been sent to the summit of Pike's Peak, and it was decided to repeat this performance with the supercharger. Fig. 2 shows the trailer truck that was prepared for the expedition. The Liberty motor carrying the supercharger was mounted on a cradle dismountable, with axles and all arrangements for accurate measurement of power, gasoline consumption, and the like. As fuel, oxygen, testing laboratory was provided. The motor truck was shipped by train to Colorado Springs, and then proceeded by the new passenger train to Pike's Peak summit at the Pike's Peak Auto Highway. This is a well established, very scenic mountain road twenty-eight miles long

Pike's Peak summit has an altitude of 14,099 ft. It is the highest point in the United States easily reached by road. The highest point is a slightly rounded, rocky flat about 100 yds. in diameter. On it are two stone houses, one at the foot of a big natural and another one about 100 yds. distant at the terminus of the auto highway. The motor truck was sent up the road, later. Fig. 3 shows the nature of Pike's Peak summit. Fig. 4 shows the way the test car was left after each day's work. Fig. 5 shows the conditions in the summit at the time of the test.

There were, however, many great and deep valleys the testing work could be carried on with facility. Fig. 6 shows the rear of the test car on a pointed day.

The testing work at the summit itself through September and part of October, 1929. The usual difficulties with experimental work were, of course, encountered with the addition of many delays, due to the cold and snow, and descent from higher slopes. Much change was made in the machine, but all the new work and changes of appreciable magnitude were made at Colorado Springs. Finally the apparatus was gotten to give good mechanical operation, and a number of tests were run showing the performance of the engine with the superchargers against up to the maximum limit possible. The supercharger was designed for operation at 16,000 ft. with some margin. It was tested at the existing altitude of 14,099 ft. and not in super charge so as to give full sea level power, but also to compare so as to make the engine to be tested.

It was agreed that results of the Pike's Peak tests warranted the immediate installation of the supercharger on an airplane, and arrangements for doing this were in progress when the airplane arrived a portion of the work. After the installation, several representatives of the aviation service were present at the work in the early part of 1929. Various arrangements were made in view of the experience gained at Pike's Peak, and the apparatus was finally started on the ground after a number of tests on the ground. Eight tests were made.

It is now developed that a very appreciable increase of power was easily obtained when the supercharger was installed. The whole airplane installation was not properly arranged to take advantage of the power, however, and the engine, and the engine was somewhat of the indicated, cooling system, propeller system, pump tank and pump system, etc. Changes in these parts have been made from time to time, and the work is still in progress. As the work proceeds more and more power will be developed by the engine. Changes have also been made in the supercharger itself.

Many remarkable flight tests have been made. In fact, during the early work a slight record of some kind or other was broken at every 1000 ft. Apparently progress has already been made, but the full advantage of the apparatus has not yet been reached, and further improvements of performance are to be expected.

Fig. 7 shows the airplane installation, and Fig. 8 shows the E. W. Holcomb, who has made all of the flight tests to date, together with George W. Allen, who has made all of the flight observations to date. The aviators are of course strapped into the airplane and at high altitudes and many the aviators are now being regularly used by the



FIG. 8. AVIATORS READY FOR HIGH ALTITUDE FLIGHTS.

## U. S. Air Service on experimental and theoretical work

## Measurement of altitude

The altitude of an airplane is measured by an aneroid which is shown in Fig. 9. This is essentially an aneroid barometer. It measures a chamber almost airtight exhausted of all air, which is a flexible metal envelope. As the atmospheric pressure varies on the displacement to a greater or less extent, the diaphragm moves in or out. This motion actuates a train of mechanical wheels, which is a needle moving over a scale. The temperature of the instrument itself must, of course, have no effect on the readings. Temperature compensation is arranged for by having a certain amount of air in the vacuum chamber, and also by use of metal in one of the levers which has an appreciable coefficient of expansion. This compensating compensation is never quite exact, however, and a slight correction in the indications must be made, to take account of the actual temperature of the parts of the instrument at the time of an observation.

The reading of the instrument with temperature compensation takes into account, given the absolute pressure at the altitude in question, and it is from this absolute pressure that the altitude is measured. Knowing the absolute pressure at the level from which the flight is made, as given by the barometer, the absolute pressure at altitude is given by the aneroid reading, and the temperature of the column of air between these two points at a number of heights, the density in this column can be computed by an appropriate formula. These calculations are collected by an automatic tabulator at various altitudes, to enable the computation to be made approximately for an average case. However, when an actual altitude record is required, the actual temperature at various altitudes during the ascent must be observed and recorded. The formula of the altitude is therefore a matter of some complexity. It has been very carefully done in the case of the supercharger flights at McCook Field.

The instrument of the type is an aneroid barometer.

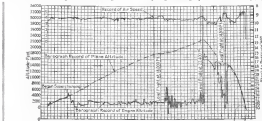


FIG. 16. RECORD OF FLIGHT OF SUPERCHARGER AIRPLANE

The instruments actually used for the final computation of altitude flight records are recording instruments called "aneroid," which operate on the same principle. Fig. 10 shows the aneroid actually used for such an instrument. After a flight the recording instruments used are removed from the plane and placed under the bell-jar of an air pump, connected with a mercury column, to hold the clock which causes the rotation of the record paper to still running. Aneroid instruments are thus obtained of a number of known values of absolute pressure, as shown by the aneroid column. This gives an accurate calibration and establishes the absolute pressure at the maximum altitude reached. During recent flights these aneroid barometers are used for verification.

Fig. 11 shows observations of temperatures at high altitudes for a great many of the supercharger flights. From the actual values of these temperatures for a given flight and the barograph record above mentioned the maximum altitude is computed.

The amount of supercharging is measured by a recording barograph of the same kind, which is not exposed to atmospheric pressure, however, but which is enclosed in a sealed chamber connected by a pipe line to the air outlet at the supercharger outlet. By means of the known temperature the altitude corresponding to the record can be known, so that there is given a record of the equivalent altitude of the engine. This is practically as used, as is shown by the lower curve in Fig. 9.

The upper curve in Fig. 10 gives a record of a maximum-altitude climb arrangement, which gives the air speed, and the engine speed, and the actual flight near the ground over a measured course of three miles with the use of stop watches.

By these methods very accurate knowledge has been obtained of the performance of the supercharger under many conditions.

## Supercharger Performance

The supercharger which has been used in this work was specially designed for high speeds at altitudes of 15,000 to 25,000 ft.

The Le Prie plane on which the installation was made had a loading of about 25,000 ft. with two men, and a speed at the altitude of 70 m.p.h. with the supercharger in use. A speed of about 140 m.p.h. has been obtained at 25,000 ft. As already pointed out, this has been with various parts of the plane installation in a partially developed state. The control computations have been made showing that much higher speeds at higher altitudes are to be expected. The progress of the flight tests in fact indicates that the theoretical expectations are not so fully realized.

The making of high altitude records has always been very attractive and the supercharger has of course been used for the purpose as well as for the speed course above mentioned. The maximum altitude achieved was in Oct. 1928 with two men, Maj. H. W. Schenck and Capt. Geo. W. Elmer. The maximum indicated altitude was 31,000 ft. The maximum temperature from very complete observations gave the second height from the ground as 31,000 ft.

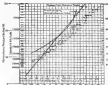


FIG. 11. TEMPERATURE AT HIGH ALTITUDES

The supercharger flights have been continued throughout the winter but with many delays on account of the weather. The work will be resumed soon rigorously in the spring.

## New Aeromarine Control

An improvement on the control system that adds not only to the safety but to the ease of operation of the Aeromarine Plane has recently been adopted by the Aeromarine Plane and Motor Co. of Elstree, N. Y. The new control will be exhibited in use in a five-minute flying hour at the New York Aeronautical Show and will appear in all new types of Aeromarine.

The system has been examined by aeronautical engineers and others whose duty it is to make flying safe that some of the mechanical and field control which occur now and then may have been caused by the shaking of pilot or passengers, or old line of control wires, used here, the control wires, pulleys or tubes around the stick. This is a matter of considerable importance, but it is certain that there is danger of exposed wire or other parts of the control system becoming loose or broken under conditions of vibration. The growing interest and participation of women in flying adds to the danger from this source, since their skirts, ready bags, etc., may easily pass a control.

The method of eliminating unnecessary wires, pulleys and other bits of mechanism exposed in the cockpit was suggested by Aeromarine engineers and a detailed improvement has resulted, an improvement which is not only to the safety of the pilot, but very markedly to the feature of compact and of clean design.

The entire control, a novel modification of the Deperdussin type, is now a single unit. All wires pass in a single bundle, and are all in a single unit. All wires pass in a single bundle, and are all in a single unit. All wires pass in a single bundle, and are all in a single unit.

The 15-in. control wheel is mounted on the end of a column made from 2-in. O.D. stainless steel tubing. A bronze track, attached to the column, works in a ground slot bearing fastened in the floor and end, and supports the column.

From the lower end of the column, and at right angles to it, a shaft projects, which is rotated by the rotation of the control wheel through lever gears and a vertical shaft. These gears are covered by ground-high brass bearings, which are made strong enough to take the push and pull of the elevator control and yet through a universal joint to a steel take-up



FIG. 12. CONTROL COLUMN FITTED TO AN AEROMARINE CONTROL SYSTEM

ring back under the passenger's seat to the rear of the gas-line tank in the tank compartment.

Acting through a universal joint attached to a shaft supported by two bearings on a rotating steel rod bracket, the take-down the column, which is drawn. In the main bracket, which is about 12 in. long, is attached the elevator control. Two of these wires run forward over pulleys and back to the lower elevator horn, the other two directly back to the upper horns. The wires attached to the elevator control drum pass over pulleys located at the front point of the bracket, supporting the drum and lower over pulleys to the lower elevator control horns.

The throttle control lever is attached to the control column and operates in much the same manner as a carburetor choke on an automobile.

## A Swedish Sporting Airplane

The Pradum Woden has constructed a light sporting, single-seater motor airplane fitted with a 50 hp. Deperdussin engine. The machine weighs 220 lbs., empty, and has a useful load, including pilot, of 150 lbs.

Two large curved mirrors, which serve as wings, are fitted to the motor-carriage, as well as a landing brake. A motor retractor is fitted over the pilot's control to prevent the pilot should the machine turn back on landing.

The wings are not fixed, but are hinged, and are moved by a single control. The surface of the fuselage is practically circular throughout, and the machine is entirely as simple as the fuselage.

The speed is given as from 125 to 130 km.p.h.—Engr. (Pilot).

# Introduction to Propeller Theory

By Alexander Klemin

Consulting Engineer, Aerial Mail Service, Consulting Aeronautical Engineer

**Notation and Definitions—Angle of Incidence or Attack.**—The angle between the direction of the relative wind and the chord of an aerofoil is indicated by  $\alpha$ . The angle between resultant velocity of relative wind and velocity of rotation of an element of the propeller is denoted by  $\beta$ .

**Chord.**—Its special definition can be followed for the chord of an aerofoil. For any aerofoil that has will be taken as the chord which the original designer has intended.

**Lift.**—The component of the force due to the air pressure of an aerofoil, resolved perpendicular to the relative wind and denoted by the symbol  $C$ . The lift coefficient is always denoted by  $C_L$ . The lift on an element of a blade is denoted by  $dL$ .

**Drag.**—The component of the force due to the air pressure of an aerofoil, resolved along the relative wind is denoted by the symbol  $D$ . The drag coefficient is always denoted by  $C_D$ . The drag on an element of a blade is denoted by  $dD$ .

## ENGINEERING DRAWING OF A TYPICAL PROPELLER



**Left/Right.** This note is denoted by L/R and the angle between the normal to the line of relative motion and the resultant air force is given by the equation  $\beta = \tan^{-1} \frac{L}{D}$ .

**Pitch angle is denoted by  $\phi$ .**  
The density of the fluid in gravitational units is represented by  $\rho$ .

**Rotation for Geometrical Dimensions of Propeller**

Radius  $r$  in ft.  
Diameter  $d$  in ft.  
Radius at any section  $r$  in ft.  
Pitch width  $b$  in ft.  
Area of an element of a blade  $dA$  in sq. ft.  
Area of elemental ring at any section of the stream  $dA$  in sq. ft.

**Rotation of Velocities of Translation and Rotation**

Translational velocity of airplane and propeller  $V$  in ft./sec.  
Infinite velocity of slip stream  $v$  in ft./sec.  
Extra velocity gained by stream after passing the screw  $v_s$  in ft./sec.

Angular velocity of propeller  $\Omega$  in radians/sec.  
Propeller speed  $\omega$  in revolutions per second.  
For rotational velocity of air before element of propeller  $\Omega$  in radians/sec.

Extra rotational velocity of air after passing propeller element  $\omega_s$  in radians/sec.  
Resultant velocity of translation and rotation  $V_r$  in ft./sec.  
Density of air  $\rho$  is represented by the symbol  $\rho$ .

**Geometrical Pitch.**—When a propeller is moving through the air, every point on the blade describes a helical path in the air, owing to the combination motion of translation and rotation. Geometrical pitch is the distance that any point on the blade would describe in one complete revolution if there were no pressure slip through the medium of that point. The mean geometrical pitch is taken at a point 90% per cent of the way from the center of the hub to the tip, this being the official U. S. Army and British Airworthiness standard.

**Mean Experimental Pitch.**—The mean experimental pitch,

denoted by the symbol  $p$ , is the advance per revolution in feet, when the propeller gives an thrust on a wheel. The experimental mean pitch or air-thrust pitch cannot be a constant for a given propeller, but depends on the speed of rotation. This is because the air-lift angle of attack varies so much as to vary the pitch change quite rapidly with speed.

**Effective Pitch.**—By this is meant the distance that the propeller actually advances in one revolution, that is, the speed in feet per second divided by the revolutions per second and is denoted as  $p_e$ .

**Lift  $p$  experimental pitch**  
 $p = \text{velocity of revolutions per second} \times \text{advance of revolutions per second}$   
then  $\frac{ap}{p} = \text{slip ratio} = 1 - \frac{p}{p_e}$

This ratio is very frequently used, although it has no definite name. It represents a relationship between the velocity of the plane, the rotational velocity of the plane and the diameter of the propeller. Geometrically similar propellers at the same value of  $V$  and  $\Omega$ , exhibit the same aerodynamic properties, and hence the form is valuable basis of comparison.

**Thrust and Torque Coefficients**

Thrust is indicated by symbol  $T$  in lb.  
Torque is indicated by symbol  $Q$  in ft.-lb.  
Power delivered to the propeller by the engine is indicated by symbol  $P$  in ft.-lb.

Efficiency is indicated by the symbol  $\eta$ .

The thrust for an element of the blade is denoted by  $dT$ .

The torque for an element of the blade is denoted by  $dQ$ .

For any given propeller, a common method of presentation of thrust and torque values is by plotting torque and thrust coefficients against the ratio  $\frac{V}{\Omega r}$ , where  $V$  is ft./sec.,  $\Omega$  is in r.p.s., and  $r$  is in ft.

If  $\phi$  is in ft. If  $T$  is the thrust coefficient  $T = \frac{T}{\rho V^2 A}$ , and if  $Q$  is the torque coefficient  $Q = \frac{Q}{\rho V^2 A r}$ .

In the present state of propeller design, it may be stated

Classification of Propeller Theories

In the present state of propeller design, it may be stated

FIG-2

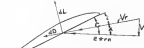


FIG-2

VELOCITIES & FORCES

FOR A BLADE ELEMENT.

that practical design is on an empirical basis, and each designer has his own preferred notation and units, which he uses more or less successfully in any new design. It is of obvious advantage to discuss the subject of empirical methods, and to base design on theory. The efficiency in any satisfactory theory has not been derived.

The various theories advanced up to date may be classified as

- (a) Simple D'Alembert or Lanchester Aerofoil Theory.
- (b) Rankine-Froude Momentum Theory.
- (c) Application of Bernoulli's Theorem to the Aerofoil.
- (d) A combination of the above theories, developed by Rankine, Froude, Page, Goldstein and other writers, which may be termed the *Rankine-Froude-Momentum Theories*.

The simple D'Alembert or Lanchester Aerofoil Theory.

The simplest theory of propeller design and the one which has reached the widest acceptance is the D'Alembert theory, which Lanchester maintained about the same time.

In Fig. 1 is shown an engineer's drawing of a typical propeller.

By a slight effort of the imagination, we can get a clear conception of the motion relative to the air which such blades

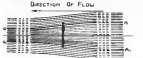


FIG-3

IDEAL CONDITIONS OF FLOW

FOR APPLICATION OF BERNOULLI'S THEOREM

element undergoes. Each blade element has the motion of translation of the propeller as a whole, and the motion of rotation about the axis of the propeller as indicated in Fig. 2.

The fundamental assumption is that this element behaves like an independent aerofoil. The resultant velocity of the element is composed of the translational velocity of the propeller  $V$  and the rotational velocity  $\Omega r$  so that

$$V_r = \sqrt{V^2 + (\Omega r)^2}$$

This resultant velocity makes with the chord of the blade element an angle  $\alpha$  which is the angle of attack.

If the blade element be further considered as an aerofoil, the usual assumption will attach to the terms lift and drag, whose values will be dependent on the angle of incidence  $\alpha$  and on the value of  $V_r$ . We are not so much interested in the value of  $dL$  and  $dD$ , however, as in the value of the force components along the axis of translation and along the line of rotation. The one will be a part of the total thrust of the propeller, the other will be a part of the torque of the propeller.

Resolving along these two axes, we have

$$\text{For thrust component } (dL \sin \alpha + dD \cos \alpha) r = dT$$

For torque component  $(dL \cos \alpha - dD \sin \alpha) r = dQ$

Multiplying these components by the translation and angular velocity respectively, the efficiency will be represented by the expression:

$$\eta = \frac{T V_r}{P} = \frac{T V_r}{\rho V^2 A r} = \frac{T}{\rho V^2 A r} \frac{V_r}{V}$$

putting  $\frac{V_r}{V} = \frac{1}{\cos \beta}$  and  $\frac{T}{\rho V^2 A r} = \eta_e$  we have

$$\eta = \frac{\eta_e}{\cos \beta} = \frac{\eta_e}{\cos \beta} \frac{1}{\cos \beta} = \frac{\eta_e}{\cos^2 \beta}$$

It is obvious that the efficiency will increase as  $\beta$  decreases or the  $L/D$  ratio of the blade increases. At the same time there is a condition of maximum efficiency for the assumption with a certain value of  $\beta$ . Thus differentiating the expression for  $\eta$  with regard to  $\beta$ , the expression will be found to have a maximum when

$$\beta = \frac{\pi}{4}$$

The absolute  $dL$  and  $dD$  can be written down in more explicit form. Thus if  $C_L$  and  $C_D$  are the lift and drag coefficients for

the blade element at angle of incidence,  $\alpha$ ,  $dL = C_L dA V_r^2$  and  $dD = C_D dA V_r^2$ .

When the thrust and torque components for the elements of the blade are integrated for the entire blade, by a process of either mathematical or graphical integration, the thrust and torque for the entire propeller are found. This constitutes the whole basis of the D'Alembert theory, and the aerodynamic basis of propeller design consists in the selection, correction and application of the above formulas.

Quite apart from the question of loss at the tip, loss at the root, interference between blades, end-vortex interference, tip lift and drag coefficients, the correct value of aspect ratio is to be assigned to any blade element, and other points, the simple D'Alembert theory does not take into account the velocity of inflow which is greater than the translational velocity of the propeller and the velocity at outflow which is still greater, the resultant velocity of the air both is found and a more or less accurate estimate of the variations in the area of the stream. Modern theories of the propeller consider an endeavor to remedy this assumption.

The Rankine-Froude Momentum Theory

In the Rankine-Froude method, the propeller is considered not as 10 separate elements but, as a whole, and the thrust is found from the force required to impart a certain momentum to the fluid.

The fundamental conception of this theory as applied to the air screw may be thus simply stated. Using the relation between the change of the mass  $M$  of a ring of air of thickness  $\delta$  of the screw,  $\delta$  is denoted velocity  $v$ ,  $\delta$  is extra velocity gained by stream after passing the screw, and calling  $dM$  the mass of the stream under consideration acted on by an element of the screw, the useful work done per second is  $dT = \delta M (v + v_s)$ .

The element of the blade contains this thrust  $dT$  on the air, but meets it at a velocity  $(V + v_s)$ , so that the work done on the air is  $dT (V + v_s)$ . The efficiency is therefore  $\frac{T V_r}{P}$ .

This is the expression for the maximum theoretical efficiency. Thus efficiency is a perfect form.

In a perfect fluid it also follows that all the work done by the element of an element of the blade as the air is converted into the air screw of infinite strength of the slip stream. From this it follows that  $\frac{T}{\rho V^2 A} = \frac{1}{2} \frac{dM}{\rho V^2 A} (V + v_s) = \frac{1}{2} (V + v_s)$  so that  $\eta = \frac{v_s}{V + v_s}$ , the expression for thrust becomes simplified, so that  $dT = dM (V + v_s) = \frac{1}{2} dM v_s$ .

Instead of considering the entire disk area of the screw may be considered in similar fashion. If  $\Delta$  is the



FIG-4

VELOCITIES & FORCES

FOR A BLADE ELEMENT.

CONSIDERING INFLUX

density of the air, and the stream is taken to occupy the entire disk area  $T = \frac{\Delta \delta V_r^2}{2} (V + v_s) = \frac{\Delta \delta V_r^2}{2} (V + v_s)$ .

In a perfect fluid, this formula would give for a given value  $T$  and  $V$  give in the inflow velocity and the efficiency maximum.

Application of Bernoulli's Theorem to the Aerofoil

In applying Bernoulli's theorem to the aerofoil, the air is

(Continued on page 154)





# Impressions of Airplanes at the Show

By Alexander Klein

The show is almost entirely devoted to monomotor machines, with almost no exhibits of a military or naval character. It demonstrates consistently that aviation has now entered as a purely commercial phase, and at the same time it gives an excellent opportunity of reviewing the entire field of monomotor design.

Commercial machines are falling entirely into certain classes, with well defined characteristics for each class. Designers and builders show refinement, simplicity and aerodynamic improvements in all the classes exhibited, and with

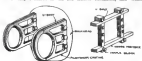


FIG. 1 LWF BUTTERFLY ENGINE MECHANISM

there are no radical innovations in any class, yet there is shown considerable originality in many machines. The general standard of both construction and design is very high, and it is evident a tremendous advance over pre-war standards.

The outstanding feature of the show is comparison with pre-war practice is the attention given to fuselage construction from an aerodynamic and structural point of view, the frequent employment of the sectional fuselage, and the presence of many intricate fuselage structures.

There is also more insistence on such points as well as on security and reliability than on the extreme performance and maneuverability of war times. There is also an effort on the part of manufacturers to meet the demands of the public



FIG. 2 WIRE TRUSS OR LWF STRUCTURE

as regards price, and to supply machines in at least certain classes at an extremely moderate price.

And the transportation machines are distinct features of the show and show remarkable possibilities of utilization.

## One-Place Sport Planes

A decided improvement is noted in the class by the LWF Butterfly, equipped with a 12 hp., 3 jet, overhead motor. The 14 hp. machine has a wing weight of 105 lb., a wing area of 115.0 sq. ft., and a wing loading of only 9.2 lb. per sq. ft., with a span of 30 ft., and an overall length of 29 ft.

The machine has evidently been built with a definite eye upon the designer's need, and shows a serious and successful attempt to meet the demand for a low priced, yet heavily simple, sporting machine.

As one of the means of obtaining support, the plane is built on a rigid frame monoplaner, which carries with it a main spar of tube, and a main spar of tube in position in the fuselage. A drawback to the use of a monoplaner design is a somewhat large span, which necessarily follows even with a small aspect ratio. There also follows an increase in overall length

in the monoplaner a larger chord must also be employed than in a biplane of the same span.

If these points are balanced against the simplicity of construction of the monoplaner, the reduced number of wing parts and the absence of interference between the two wings of a biplane, it may be safely said that there is very little to choose between a biplane or a monoplaner, for the small type of machine.

The general appearance of the Butterfly is very good and clean. In an early model of the machine the wing was carried high above the body. By bringing the wing level with the top of the body the designer has considerably improved the balance of the job, as well as simplifying the drawing. It is fully to be expected that with the low wing loading and the low power loading the machine will have both a low landing speed and short landing run, so well as a quick get-away.

The heavily monomotor body is of the usual LWF construction, and presents a very neat and sturdy appearance. The landing of the wing is shown to be highly satisfactory. The main lift struts are perfectly adjustable in strength, as they stand, and the short struts covering of half their length



FIG. 3 CONTROL SYSTEM OF LWF BUTTERFLY

will effectively prevent a tendency to bending. The general scheme of the wing trussing is shown in the accompanying sketch. It is obvious that the bracing in the drag should also be simply sufficient. An external drag wire is carried as an additional safeguard from the rear strut point to the front part of the body.

Apart from the simplicity of the general design, a number of interesting detail features are present. On all of the steel tube structural fittings are provided, so that all fittings are interchangeable, with up built covering and hand tight ends. The external drag wire is connected to what amounts to a universal joint at the fuselage, which is an excellent guarantee against break-down by vibration.

The engine mounting is particularly interesting. The motor is clamped between two aluminum castings by two C-clips which form the motor in an aluminum backbone, which fits into the top of the monomotor fuselage.

Another machine in the one-place sport plane class is the Harnett-Kennedy model K-1, which was specially exhibited at Hensel Veldkamp.

The Harnett-Kennedy model K-1 is a tractor biplane of 26 ft. span, 15 ft. 6 in. overall length and 8 ft. height. It is fitted with a 40 hp. Harnett-Kennedy engine of the 4-cyl. vertical water-cooled type, which gives the machine a maximum horizontal speed of 80 m.p.h. and a landing speed of about 30 m.p.h. The machine weighs fully loaded 830 lb.; the wing

loading is 4.5 lb. and the power loading 20.0 lb., which figures should give the pilot considerable maneuverability.

The wings are designed to fold back against the fuselage by moving their pins from the front and at the outer section. The overall dimensions of the K-1 are thus reduced to 20 feet 6 in., which is a very valuable feature for storing the machine or for moving her on the road.

The fuselage is of the four bay type, braced by vanees, bulkheads and covered with plywood skins. It has a good streamlining and a generally pleasing appearance.

The landing gear is of the V type, with a center strut to prevent rolling over.

## Passenger Machines—Flying Boats

In a definite class by themselves are what may be termed touring machines carrying more than two passengers. No less than three of these machines carry the Hispano engine.



FIG. 4 HISPANO ENGINE CONTROL

series. Designers seem to have met the requirements for touring and touring biplanes in very good fashion, and there is no doubt that machines with a pilot and two or three passengers will find a considerable market among them. They are still apparently different of opinion as regards the relative advantages of giving the passengers a considerable cockpit fuselage, and the disadvantages of depriving the pilot of a certain amount of vision and feel in the air. No attempts have been made to secure good speeds, these machines being either in or in the neighborhood of 100 m.p.h.

An entirely new machine in this class, and perhaps the most interesting of them, is the Grinnel-Turner, built by the Grinnel-Turner Engineering Corp. The span of the ship is 34 ft., overall length 54 ft. 10 in., gross weight 2,500 lb.,

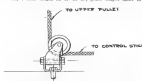


FIG. 5 GRINNEL-TURNER CONTROL SYSTEM

and the wing loading is 10.5 lb. with a 100 hp. Hispano. The power loading is 30.0 pounds per horse power, carrying a pilot, 3 passengers, baggage and fuel. It is estimated that the machine can cover 200 miles at the high speed of 90 m.p.h. per hour. The designer of the Grinnel-Turner has tried to employ the simplicity of the machine. They are seated side by side with the dual control in the front cockpit. The controls are very well placed with the dual control in the front cockpit. The machine has a very pleasing general appearance and is very easy and handled in design—these features are especially noticeable.

Production possibilities have been very well taken care of. All struts are exactly alike and are of straight section, easily made out of a single piece with the ends merely turned off for the tapering effect. All the ribs are also straight and the machine. The top and bottom wings are completely interchangeable. The propeller also has been turned out in many other details. One of the shortcomings show the single way in which a small but big step provides a support for the control pulleys. Steel fittings are all of the single type-like type.

The control system of the Grinnel-Turner is worth considerable interest. As shown in the sketch, the elevator and aileron dual control is built in of square tubing. This provides very easy and maintenance. The elevator arms also fit very well on to a square tube and there is no possibility of the elevator arms bending through small pins, or in other the case.

The sketch of the control system also indicates the great simplicity of the aileron system. By means of four pulleys, a couple of 3/16-in.-diameter struts and wires, with the main wires in the front plane of the control cable, when needed, all aileron wires are avoided. The designer of this control system may well be congratulated upon the simplicity and economy of his design.

The chassis, as shown in the sketch, also gives evidence of a careful production outlook. It is a ponder thing how well a wide body frame to work out in a design of this type

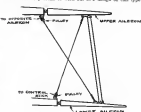


FIG. 6 GRINNEL-TURNER CHASSIS

Granted that a wide body means a certain amount of extra aerodynamic resistance, a number of advantages derive from it as well. For instance, with the ordinary width of track, the struts are straight down, the Hispano engine is completely enclosed, the chassis connection to the forward struts work out beautifully. In general, it is quite possible that a wide body may have so many advantages that its slight increased resistance may be fully compensated for.

The engine mounting of the Grinnel-Turner is very well built. The engine is carried downwards at the rear side to avoid the negative. Three steel bulkheads of small gauge but of heavy channel, together with welded tubes, detaching from the rear bulkhead to the front bulkhead, provide a structure which should take care of wearing and other severe strains.

The gasoline system is simple and good. The tank is placed under the front seat. The main drive pump is easily fastened to the rear chassis strut and makes use of an overpressure than backing pressure from. The gas line side provides ample security for the pilot regarding his gasoline system.

The West Virginia Aircraft Corp. exhibited in the class of machine a three-seater built around the 100 hp. Wright Hispano engine. The two passengers are seated ahead in a short cockpit, while the pilot is accommodated aft. The

machine is a good solid construction, but is so standardized in type as to call for no special comment.

The engine is 40 h. p., 540 in. on the upper plane and 56 h. p., 540 in. on the lower plane. The overall length is 37 ft. 34 in. and the height is 7 ft. 8 in. The wing area is 1,000 sq. ft. The wing loading is 15.5 lb. per sq. ft. The engine is mounted on a semi-rigid angle of incidence of 3 deg. 5 min. and at a dihedral of 1 deg.

The machine weighs empty 1,700 lb. and fully loaded 2,400 lb. The estimated performance is as follows: maximum horizontal speed 50 m.p.h., maximum flight speed 40 m.p.h. and climb 4,000 ft. in 10 min. The wing loading is 15.5 lb. per sq. ft. and the power loading 16 lb. per sq. ft. The Curtiss Cycle seems to be a sound design for this motor ship. The pilot has a reasonable position for each where he has unobstructed vision and a good control of the machine. The passenger in front is provided with an efficient seat which The structure of the motor fuselage is very good, and its construction is thoroughly sound. The engine is fairly well

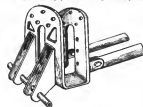


Fig. 7. Ground Landing Gear Fittings

of streamlines from its main parts as present above the fuselage, and it is all the better for even cooling, besides being readily accessible. Powered with 120 hp., the machine has ample performance and a fairly low landing speed. It may be considered as a well finished and well balanced design.

The Bristol Taurus, which was originally designed at the Bristol Aeroplane Co., is a high powered machine, is equipped to carry only a pilot and a passenger. It has however a large fuel supply, and when used as a mail ship can carry over 300 lb. in addition to the full complement of fuel and oil. Equipped with a 250 hp. Stanley Price engine, it can obtain a maximum speed of 120 m.p.h.

The Bristol Taurus is a modification of the familiar Bristol Fighter, and is therefore of well known and familiar construction. It is a sturdy, well balanced and maneuverable machine, which should have a decided sphere of action for fast mail and freight carrying, with a bonus appeal for pleasure passenger work.

The appearance of the machine is very much better than that of the Bristol Fighter, owing to the disappearance of the gun turret, the lowering of the nose cockpit, and the resulting improvement in the flow of the machine.

The main characteristics of the machine are: weight, empty, 1,700 lb.; weight, loaded, 2,400 lb.; wing area, 20 ft. 3 in.; wing area, 400 sq. ft.; wing loading, 15.5 lb. per sq. ft.; climb of 4,000 ft. in 10 min.; overall length, 37 ft. 34 in.; tailage-guns, 30 ft. 8 in.; tailage, 20,000 ft.

#### Stinson Explorer

A very interesting machine is the Aeromarine Model 50. This is a biplane finished construction, and is most interesting machine. Some sketches are shown of the steady engine, the solid tail bracing, and the interesting tail arrangement.

The machine is illustrative of a good many features of modern conventional design, and has very close lines at the same time it does not depart from standard practice.

A step is provided for access into the tail, which arrangement should appeal to the public as it facilitates access and egress. The seats for the pilot and the two passengers are most comfortably appointed. The two wingtips curve in

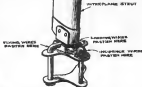


Fig. 8. Basic Fittings of Curtiss Eagle

either side do not interfere in any way with the straightened strength of the tail. A number of small doors and compartments are provided in front of the pilot and at the sides of the machine. The controls are as arranged as to leave the cockpit entirely free of wires; thus the roller bar is displaced by another bar to which it is connected by wire control beneath the floor. A wheel control is provided, but with this important modification that the movement of the wheel is transmitted through lever gearing, in gear shafts made of steel control column and is carried out to a horizontal shaft with a universal joint at the other end. Elevator and

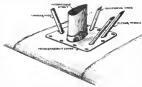


Fig. 9. Taurus-More Street Fittings

ailerons control is directly achieved without a single wire connecting the cockpit.

While the passenger and pilot are totally isolated, the vision is quite good through transparent panels, and the pilot has a number of movable windows in front of him. A conspicuous feature of the fuselage design is the distance angle between the front radiator and the engine. The radiator might be almost considered a Curtiss radiator.

The Curtiss design in motor machines of this three motor flying boat type, approximately of the same size as the Aeromarine Model 50. Equipped with the Curtiss 250 hp. engine, it obtains a maximum speed of 70 m.p.h. and a maximum of 48.5 m.p.h. This machine is in many respects similar to the

Curtiss MF boats used so extensively during the war for the training of Navy Aviators, and the main modification of the MF are in the arrangement of the hull, in which a pilot or two passengers are carried.

The hull is provided with a much larger wheel-should than is customary in training planes, and lots of lip-iron is provided for all the compasses. A motor engine is fixed in the front control stick. The rear control being further back on the side, the front stick is bent under the seat so that it works on the same shaft as the rear control stick. This is a very clever piece of design, to get around what is always a difficult problem. It is interesting to note in this machine the use of aluminum wing ribs, which curve right up to the wing, and require only one wire for lateral bracing.

In the wing track of the Douglas it is noticeable that two large shuttles are provided although there is a dihedral in the machine. The 14 ft. track is so arranged that the wing hinges are carried out at some distance from the hull, by

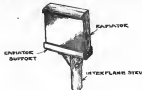


Fig. 10. Radiator of Curtiss Eagle

the introduction of a pair of extra struts on either side. The bracing is orthogonally placed as a great advantage in the mounting of a flying boat engine.

#### Curtis Eagle

A very interesting modification of the Curtiss Eagle was exhibited at the show. Instead of the three K-6 motor previously installed in this plane, the Eagle now carries four Curtiss 250 hp. engines mounted on the wings.

The Eagle is a sturdy, well-designed plane of presently smart appearance, with adequate vision for the pilot. The main fuselage, on first viewing, was regarded with some doubt as to its aerodynamic properties, but a high-speed test clearly indicates that very little detrimental effect is produced thereby.

A number of features in the construction of this ship are worthy of note. The radiator mounting is very neat, while it is generally admitted that the two air radiators in the largest in height and aerodynamically most efficient. Inexpensive have always found a difficulty in finding a suitable place for the installation of such a free air radiator. In the present design the radiator is mounted in front of the air ducting. The radiator tank fits very neatly into the front edge of the upper wing. The well designed wing train has no outstanding protrusions, with the exception of the air-braking device on the struts, shown in the sketch. No doubt the Curtiss engineers have made careful calculations in this respect, and have found advantage in lightening up the struts, even when the extra head-pressure of the air braking device is taken into account.

Main structural work has been done on the large mounting of the engine nacelles which is well conceived. This, of course, involves a slightly heavier construction, but is obviously counteracted by the balance. When three engines were employed, a complete set of engines had previously provided the necessary balancing masses.

The fitting of the upper windows in the motor fuselage is very close, as shown in the sketch.

Another structural feature which is of interest is a cleav-plate with a cleav-plate, which is a decided advantage in securing a short distance run. The hull design seems to have no effect on ordinary flight.

The landing flaps on the exhaust are decidedly used features, and should work very efficiently.

The position of the window in relation on either side is a security against over-exposure of the machine, and also pro-

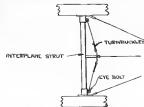


Fig. 11. Curtiss Eagle Air-Braking Tabs

vide for a very solid construction. The fitting of the cleav-plate on the exhaust may also be a useful feature in rough landings.

Another feature exhibited at the show was the Douglas Wright motor G.W., a typical of 60 h. p. and 28 ft. 9 in. overall length, which is fitted with a 180 hp. Wright-Hispano engine. Accommodations are provided for a pilot and two passengers and sufficient fuel is carried for a flight of 500 mi.

A noteworthy feature of the G.W. is the hinged body, which is necessary to give the rear of the motor with the upper engine. As a consequence the cabin is very spacious and the compass is attached to a satisfactory view of the ground below, but at the same time the pilot sits some distance from the front window, which is not so satisfactory for navigation.



Fig. 12. Section of Window of Curtiss Eagle

It is interesting to note that this machine has a very light wing loading, only 15.5 lb. per sq. ft., and a net weight of 1,400 lb., which are good figures for a plane of this size.

From the constructional viewpoint it is rather surprising to see such a well constructed motor ship employed on this plane.

The other Douglas-Wright machine, the Liberty Trainer, is a much more powerful ship, being the Liberty Trainer. The machine has not exactly speaking a wheel, for a permanent air structure is understood under this form. For the airframe and structure are subjected to the weather by a large area of exposed outside windows. The vision is good and as is common the aerodynamic area is suitably reduced.

The K.Y. has a high horizontal speed of 120 m.p.h. and a low speed of 50 m.p.h. The net weight is 2,000 lb. and the gross weight 4,328 lb. The radius of action, at a cruising speed of 100 m.p.h., is 6 h.





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
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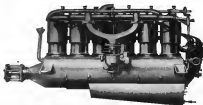
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